Canadian Stock Assessment
Proceedings Series 98/05

Évaluation des stocks canadien
Séries des comptes rendus 98/05

Report of the PSARC Salmon Subcommittee Meeting March 18, 1998 and the Steering Committee Meeting March 20, 1998

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March 1998

Fisheries and Oceans Canada
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102-06521/

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PACIFIC STOCK ASSESSMENT REVIEW COMMITTEE

PSARC ADVISORY DOCUMENT 98-2
MARCH 1998

PACIFIC SALMON

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I. STEERING COMMITTEE REPORT

The Steering Committee met March 20, 1998 in the Conference Room at the Pacific Biological Station to review the Salmon Subcommittee report. The report was accepted, with the following comments and recommendations. The Steering Committee thanked the Subcommittee Chair for a useful and well organized report.

Major Subcommittee Discussion and Concerns

Steering Committee notes the large uncertainty in the South Coast coho forecast and recognizes the serious coho conservation concerns for coho stocks originating from the Strait of Georgia, Fraser River and Johnstone Strait.

Steering Committee notes that there have been improvements in the chum forecast for South Coast inside chums that now incorporates the retrospective analyses.

Steering Committee recommends that advice on requirements for frequency and need of forecasts be referred to the Stock Assessment Coordination Committee.

S98-1 Run size forecasts for Fraser River sockeye.

The Steering Committee endorses the recommendations. The Steering Committee notes that the forecast includes only 4 and 5 year old sockeye, but not jacks.

S98-2 WCVI chum salmon forecasts for 1998.

The Steering Committee endorses the recommendations. Steering Committee notes that in 1997 the coho bycatch in prosecuting west coast of Vancouver Island fisheries for surplus chum was 300-800.

S98-3 1998 forecasts for Johnstone Strait, Georgia Strait and lower Fraser River chum salmon.

The Steering Committee accepts the recommendations, but notes that due to continuing declines in ocean survivals, the forecast remains uncertain.

S98-4 An update on the 1997 stock status and 1998 forecasts of Barkley Sound sockeye.

The Steering Committee accepts the recommendations in the working paper and supports the use of the SStM model generated forecasts.

S98-5 1998 forecasts of marine survival rate, marine distribution and pre-fishery abundance for southern B.C. coho salmon.

The Steering Committee accepted the working paper recommendations.

The Steering Committee is extremely concerned with forecasts for extremely low abundance of coho originating inside (Strait of Georgia, Fraser River Johnstone Strait) and outside (west coast Vancouver Island) in 1998.

The Steering Committee notes that there is a 10% probability that the abundance of coho originating from inside areas will be less than 216,024 and abundance of coho from the outside areas will be less than 92,994. There is a 25% probability that the abundance of coho originating from the inside areas will be less than 278,126 and from the outside areas less than 126,818. There is a 50% probability that the abundance of coho originating from the inside areas will be less than 363,607 and abundance of coho originating from the outside areas will be less than 176,225.

The Steering Committee notes that due to large uncertainties in the forecast, there is a significant chance that the abundance of the inside aggregate will be lower in 1998 than in 1997. The Steering Committee also notes that marine survival and the abundance of the inside aggregate are trending downwards. For this reason, extreme caution should be exercised in the application of the forecast.

II. SALMON SUBCOMMITTEE REPORT

1. Introduction

The PSARC Salmon Subcommittee met March 18, 1998 at the Pacific Biological Station, Nanaimo. The purpose of the meeting was to review salmon forecasts. Five working papers were presented to the Subcommittee. Meeting participants and reviewers of working papers are listed in Appendices 1 and 2, respectively.

2. General Subcommittee Discussion and Concerns

The Thompson coho stock status and forecast paper, scheduled for the spring PSARC meeting is an important component of the coho assessment package, since it is anticipated this stock may be the greatest conservation concern and have the poorest survival and abundance forecast.

The Subcommittee notes a lack of compliance with previous PSARC recommendations that specified a minimum standard for forecast papers, to include retrospective analysis (including model performance evaluation methods as outlined in Welch et al., PSARC S94-16), and estimates of uncertainty in the forecasts.

The Salmon Subcommittee requests clarification of the relative priority of stock forecasts that PSARC review each year. The Subcommittee understands the need to review Fraser sockeye and southern coho forecasts annually, but questions whether mainland chum or the WCVI chum need to be reviewed annually once the methods are accepted.

3. Working Paper Summaries, Reviews and Discussion

S98-1 Run size forecasts for Fraser River sockeye. A. Cass **Working paper accepted subject to revisions**

Run size forecasts for 1998 Fraser River sockeye returns are based on methods previously approved by PSARC. Forecasts are made for 19 individual sockeye stocks and four migratory timing/management groups. Based on escapements in the brood year, the major stocks anticipated in 1998 are the Late Shuswap (Adams River), Quesnel, and Chilko runs. The 1998 cycle year is noted for the dominant Adams River run that has historically been the single most important sockeye run on the 1998 cycle line. As reflected in the present forecast, the importance of the sub-dominant Quesnel Lake run now rivals the Late Shuswap run. The sub-dominant Quesnel run has increased exponentially since the mid-1970s. Together, the Late Shuswap and Quesnel runs accounted for 59% of the spawning escapement in 1994.

For most stocks, forecasts are based on regression models that use spawning escapement to predict adult abundance of age-4 and age-5 sockeye. Additional explanatory variables are available for some stocks and include fry, smolt and sibling adult run size estimates. Also evaluated is a method that incorporates attributes of escapement-based and juvenile-based models by pooling results from individual forecast models where time series of different life stages are available.

All years in the available time series of data were used in the analysis for each stock. Run size and escapement data are approximately log-normally distributed and for all models a log-normal error structure was assumed. The simplest forecasting models used are all-year mean and the cycle line mean returns. Historical means serve as benchmarks to judge the information content of models that incorporate explanatory variables. The next level of model includes time series of adult spawning escapements to forecast future generations of adult returns. The third levels are models that use abundance estimates measured at different ages of the same generation. These include sibling models that use adult returns to explain older returns from the same cohort. Also, included in this category are estimates of fry (Nadina, Gates and Weaver sockeye), fall fry (Quesnel and Shuswap) and smolts (Chilko sockeye) as well as a significantly correlated precipitation/environmental index used to explain ocean survival effects on run size of Chilko sockeye.

Model performance was evaluated in a retrospective analysis by comparing run size forecasts to estimated (observed) run sizes for years that estimates are available.

Starting with the most recent year that estimated returns are available (1997), a retrospective forecast for that year was made from the time series of explanatory variables by leaving out the most recent return data. In this way, retrospective forecasts for each year are based only on the time series available prior to the year being forecast. For stocks with >40 years of data retrospective comparisons were made for years 1970-94. Forecast data for most major sockeye stocks are sufficient to assess performance during that period. Stocks with fewer years of data (subsets of early Stuart, Scotch and Fennell sockeye) and other stocks recently supplemented by hatcheries (late Nadina, Gates and Weaver) were only evaluated for the 1980-1994 period.

The time series of fall fry data for Quesnel and Shuswap Lakes are short ($n \leq 10$) and of insufficient length to compare their performance in the retrospective analysis described above. Instead, a leave-one-out cross validation method that retrospectively forecasts every year in the time series was used to compare forecast performance among models.

Forecast errors were quantified using the root mean square error (RMSE) criteria. The model with the lowest RMSE was judged to be the 'best' forecast. If the RMSE criteria failed to differentiate among competing models then the model with the smallest variance was selected.

The 'best' forecast by stock and timing group at various probability levels are presented in Table 1. For all models the uncertainty associated with stock-specific forecasts are large (Table 1). Sibling models that use jacks to forecast age-4 returns are unlikely candidates for reliable prediction of age-4 returns in 1998 (jack returns in 1997). The proportion of jacks in many stocks underwent a long-term decline since the 1960s as somatic growth rates declined. Except for Stellako sockeye, correcting for the trend in jacking rate by using jack standard length as an additional explanatory variable was unsuccessful. Furthermore, anomalous migratory behaviour in 1997 resulted in high rates of straying of Fraser bound sockeye to non-Fraser systems and non-natal Fraser systems at unprecedented levels. Although still being investigated, the high rate of straying appears to be negatively correlated to body size (S. McKinnell, DFO, personal communication). If smaller fish were more likely to stray in 1997 then spawning ground estimates of jacks are likely biased low. The number of jacks estimated to have returned to Fraser River spawning locations in 1997 (1998 brood) dropped dramatically compared to returns in 1993 (1994 brood). For example, the estimated return of Late Shuswap jacks was 19,000 in 1993 compared to 600 in 1994. Except for Chilko and Birkenhead sockeye, jack returns in 1997 were in the 100s of fish. Most runs in 1997 were comprised of < 1% jacks. Based on preliminary 1997 estimates, the only stocks with escapements >1% jacks were Birkenhead (4%), Gates (20%), Shuswap (42%) and Chilko (1.4%). At jacking rates experienced by most stocks in 1997, the effects of measurement error alone are likely to render jack-based sibling models unreliable. For these reasons, jack-based forecasts are not considered in this analysis. To accept the alternative hypothesis whereby the jacks in 1997 are representative of age-4 sibling abundance in 1998 is to assume unprecedented and catastrophic low survival of the 1994 brood.

The total 1998 Fraser sockeye run size forecast based on the 19 stocks considered in this report at the 50% probability level is 11.2 million sockeye (50% chance the run will exceed this forecast), and 6.8 million at the 75% probability level (75% chance the run will exceed this forecast). Forecasts by management group are 175,000 (50%) and 97,000 (75%) for Early Stuart, 640,000 (50%) and 300,000 (75%) for early summer stocks, 6.6 million (50%) and 3.9 million (75%) for summer run stocks and 3.8 million (50%) and 2.6 million (75%) for late run stocks. Results presented here concur with previous analyses that forecast models of Fraser sockeye perform poorly. No single method, including sibling models that theoretically account for most of the natural mortality incurred by a cohort, has performed consistently better than any other.

The most important stocks in 1998 based on forecasts presented here are Quesnel (summer run) at 4.3 million and Shuswap (late run) at 3.0 million sockeye (50% chance the run will be higher or lower). Forecasts for Quesnel and late Shuswap sockeye will form the basis for the early season management strategies of sockeye fisheries in 1998. Table 2 shows the uncertainty in forecasts. For Quesnel sockeye there is only a 50% chance the run will be within 2.5 million and 7.5 million sockeye. For the late Shuswap run the range is narrower at 2.0-4.0 million sockeye. These are large ranges for only a 50% chance of the run occurring within these levels.

The major impediment to improvements in accuracy of pre-season run size forecasts is related to our inability to model variations in ocean survival. Much of the information on survival predictions from ocean climate studies is qualitative in content and difficult to consider in the statistical framework of forecasting models. The environmental index used to explain variation in Chilko ocean survival has worked to some extent, whether spurious or not, and is the only variable examined (to my knowledge) that is correlated to smolt survival.

Low-frequency climatic changes that are implicated in turn to cause autocorrelated recruitment patterns in fish population (low and high survival regimes) are not evident in the time series of Chilko smolt ocean survival data. Chilko ocean survival based on age-1 smolts to adult age-4 survival have ranged from 1.2% in brood year 1957 to 23% in 1986 and above average in 1992 and 1993 at 13% (long-term mean = 9.2%). The trend in smolt survival reveals little discernible recruitment pattern and the autocorrelation is insignificant at a lag of 1 year (r=0.18). The low correlation in inter-annual recruitment for at least Chilko sockeye (the only stock with smolt-return data) suggests that ocean survival in 1998 cannot be reliably predicted from recent survival or climatic trends. There is certainly no evidence based on the most recent two years of data to indicate sockeye are in a regime of low ocean survival. However, it is important to note that ocean temperatures in 1997 were extremely high. The impact of high temperatures on sockeye returning in 1998 is not known but managers may opt for a conservative management approach until in-season run size estimates become reliable. In-season indications of small fish size and low fecundity that may result from recent high ocean temperature should be considered to temper target escapement projections.

Subcommittee Discussion

The Fraser forecast paper represents a thorough and complete review of the forecasts using well established methods. The Subcommittee discussed the utility of the hydroacoustic fry data and noted that technology exists to improve the data if the expenditure is warranted. The authors will explore with the Fraser Lakes Production Group to more clearly evaluate the merits of supplementing the current surveys. The Quesnel forecasts using fall fry abundance is much lower than the other methods. The fry data is less certain than the data used for other forecasts. The Subcommittee asked the author to revisit the fry data to see if the fry size corroborated the low fry abundance (this was done and there was not an indication of the large fry size expected for a low fry abundance). The Subcommittee believes the fry data accuracy is suspect and does not endorse the forecast using fry data alone.

The Subcommittee also noted the very unusual climate conditions in 1997-1998 and the potential for lower than normal Fraser sockeye survivals. The author noted survivals in recent years have been average and there is no technical basis to evaluate potential effects of the unusual temperate regimes on the 1998 returns.

Subcommittee Recommendations

1. The Subcommittee recommends Fraser sockeye forecast probability distributions as outlined in Table 1. The total 1998 Fraser sockeye run size forecast based on the 19 stocks considered in this report at the 50% probability level is 11.2 million sockeye (50% chance the run will exceed this forecast), and 6.8 million at the 75% probability level (75% chance the run will exceed this forecast). Forecasts by management group are 175,000 (50%) and 97,000 (75%) for Early Stuart, 640,000 (50%) and 300,000 (75%) for Early summer stocks, 6.6 million (50%) and 3.9 million (75%) for summer run stocks and 3.8 million (50%) and 2.6 million (75%) for late run stocks.

S98-2 WCVI chum salmon forecasts for 1998. W. Luedke, and D. Bailey.
Working paper accepted subject to revisions

Forecasts of chum salmon returns are presented for two areas on the WCVI with potential commercial chum fisheries, namely Nitinat (Area 21/22) and Nootka Sound (Area 25). For Nitinat, the recommended forecast is approximately 1.2 million total return to Nitinat River and Hatchery. For Nootka Sound (Area 25) the recommended forecast is approximately 300,000 chum salmon total return to Nootka Sound.

The authors state that these forecasts are meant as a guide in pre-season planning, to help resolve allocation and economic issues regarding these fisheries. Forecasts of west coast Vancouver Island (WCVI) chum salmon adult returns are not used in the actual determination of fishing opportunity and should not be construed as obligations on the part of Fisheries and Oceans Canada. Instead fishing opportunities are based on application of in-season management and assessment regimes specific to each area.

Subcommittee Discussion

Data are limited for preparing forecasts, in particular, the quality of escapement data are poor and age composition is not available for many stocks.

With respect to the methodology used, advice was provided to authors to generate estimates of uncertainty for forecasts, to describe the environmental scalar used in Model 3 in more detail, and for the future, develop an environmental scalar that is reproducible by others. Advice was also provided to modify how Model 1 (long term average) was analyzed in the retrospective analysis; i.e. the years from 1991 to the year prior to the forecast year should be included in the average.

Subcommittee Recommendations

1. The Subcommittee recommends that the point estimate forecasts of 1.2 million for Nitinat chum and 0.3 million for Nootka Sound chum be adopted as WCVI chum forecasts for 1998.

S98-3 1998 forecasts for Johnstone Strait, Georgia Strait and lower Fraser River chum salmon. D. Bailey, V. Palermo, and P. Ryall. **Working paper accepted subject to revisions**

The 1998 return forecast is comprised of four separate components: wild non-Fraser (wild chum include the progeny of both wild and enhanced chum which spawn in natural spawning areas); wild Fraser River, enhanced non-Fraser River and enhanced Fraser River. Existing major facilities in the Strait of Georgia and the lower Fraser River have the capacity to produce 1.3 million chum at favourable marine survival rates. The major facilities on Vancouver Island include Big Qualicum, Little Qualicum spawning channel and the Puntledge Hatchery. They have a production potential of about 650,000 adults. Major facilities on the Fraser River include the Chehalis, Chilliwack and Inch hatcheries; these have a production potential of about 250,000 (not including habitat restoration). An additional 400,000 production occurs from various minor facilities and habitat restoration projects within the Study Area.

The authors compared the forecasting performance of seven models. The models used are similar to those documented in Wood et al. (PSARC S95-12). Model 1 is the long-term average return by calendar year (AVGCY). The next model examined used the average of the most recent 5 calendar year returns as the forecast (5YAVGCY). Model 3 (5YAVGBY) is similar to Model 2, except the abundance was totalled from brood year returns using the long term average return-at-age of 3, 4 and 5 year olds to determine the contribution from each brood year. The remaining four forecasting models are linear relationships between recruits and spawners. The independent variable is spawning escapement (S_t) in brood year t and the dependent is recruits (R_t). Models 5 through 7 use three through five most recent year averages of the "a" parameter rather than the

long term average used by Model 4. Models 4 through 7 were termed LSRESC, 3YLSRESC, 4YLSRESC AND 5YLSRESC, respectively.

The results of the retrospective analysis are not conclusive, no one model outperformed the others. The RMSE and MAD was lowest for the 5YLSRESC model. However, the RMSE and MAD ranges among the models were quite small. Plots of the AVGCY, 5YAVGCY and 5YAVGBY reveal that they follow the general upward trend in Study Area chum salmon returns over the period 1965-96 but, do not capture the wide fluctuations seen in chum returns. On the other hand the linear spawner/recruit relationships better captured the wide fluctuations in chum returns over the period 1965-85 they were less successful in more recent years. It would appear that the best model out of the seven examined may be the 5YLSRESC for predicting returning runs based upon the RMSE and MAD criteria.

However, the authors were not completely satisfied by this conclusion for two reasons. Large forecasts were generated for return years 1996 and 1997 (4.1 and 4.9 million, respectively) from the large escapements of 1991 through 1994. The actual return in 1996 was only about 1.5 million and while a final run size estimate is not yet available for 1997 the in-season estimate is only 2.6 million total return.

Plots of survivals from enhanced facilities at Big and Little Qualicum, Puntledge, Chehalis, Chilliwack, Inch, Stave and Blaney covering brood years 1978-92 show a large decrease in marine survivals since the 1988 or 1989 brood year (Figs. 1 and 2).

Given the large decreases in marine survivals as observed at all major Study Area facilities in recent years and the equivocal results from the retrospective analysis, the authors decided to use the 3YLSRESC model to predict the 1998 return for the wild component of Study Area chum salmon and average of most recent 3 year marine survival for enhanced component.

The 1998 forecast returns are shown in Table 2. The total Study Area return is expected to be 3,694,000 (50% probability of a lower return). This is substantially less than the 1997 forecast of 4,865,000. While the 1997 Study Area chum salmon run has not yet been reconstructed, the preliminary in-season estimate of abundance is 2.6 million. Forecast uncertainties are provided for the wild component of the returning chum stock only (Table 2).

Subcommittee Discussion

The working paper was accepted, noting Subcommittee recommendations for additional analysis required for subsequent year forecasts.

The Subcommittee noted that the forecast models used were previously accepted by PSARC in 1988. These forecasts allow fishery managers and industry to initiate pre-season management planning and allocation. The in-season management plan is based on in-season assessments of return abundance. The Subcommittee noted the RMSE for

all models were high, that is that all models were poor predictors and there is no clear choice of a preferred model. The Subcommittee suggested exploring the use of the Mission Downstream chum fry data for the Fraser River component of forecasts. In recent years there has been a downward trend in marine survivals as shown in Figs. 1 and 2.

It is noted that the forecast of return for 1998 (based on the most recent 3 year average Ricker a value) may be optimistic given the downward trend in marine survivals for return years 1993-96.

The validity of the escapement data used in this report (particularly for the Fraser River) needs to be evaluated as recent data collection methods have been significantly altered from previous approaches.

Subcommittee Recommendations

1. The Subcommittee recommends adopting the 1998 return forecast as shown in Table 2. The total Study Area return is expected to be 3,694,000. This is substantially less than the 1997 forecast of 4,865,000.

S98-4 An update on the 1997 stock status and 1998 forecasts of Barkley Sound sockeye. K.D. Hyatt and W. Luedke. **Working paper accepted subject to revisions**

Recent years returns of Barkley Sound sockeye have been gradually increasing from a low of only 200,000 fish in 1995 to 380,000 in 1996 and 465,000 in 1997. Although moderate, recent increases were anticipated by two independent forecasting procedures first developed in 1987 and applied annually since 1988 to predict returns of Barkley Sound sockeye. The forecast gradual recovery of the stock provided aboriginal, recreational and commercial fisheries opportunities in 1997. Recent year stock increases represent a continuation of a pattern of predictable variations in ocean climate states that have lead to repeated "crashes" (1978, 1985-86, 1989-90, 1994-95) followed within 1-3 years by recoveries (1979-81, 1987-88, 1991-93, 1996-97) of WCVI sockeye returns. The small surplus for commercial catch in recent years is directly attributable to the combined effects of: (i) a shift of conditions in the marine environment that supported near average survival of sockeye smolts migrating seaward between 1994 and 1996 and (ii) management to protect escapement as a basis for increases in future year returns.

Over the past 10 years, four independent techniques have been tested annually for their utility in generating reliable pre-season forecasts of Barkley Sound sockeye returns for harvest managers. The four techniques are known as the Salinity Survival Method (SSM), the Survival Stanza Method (SStM), the Sibling Age Class Method (SACM), and the Salmon Enhancement Program Biostandard Method (SEPB). Updates on the performance of three of these techniques to 1997 are as follows:

(1) The SStM forecast exhibits the best overall performance with a Mean Absolute

Percent Error (MAPE) value of approximately 27% over the most recent 10 years of forecasting. Further, SStM forecasts account for the majority of variations in returns if the extreme observation associated with the 1991 return year is omitted from the analysis (returns= 1.17 SStM forecasts - 66.35, r^2=0.82, p<0.01).

(2) The SSM forecast exhibits the next best performance with a MAPE value of 37% over the most recent 10 years of forecasting. SSM forecasts also exhibit a statistically significant association with returns if the 1991 return year is omitted from the analysis (returns= 0.83 SSM forecasts + 35.28, r^2=0.77, p<0.01).

(3) SEPB forecasts have performed well over some return intervals but not others. During the 1988-1997 testing interval SEPB forecasts exhibited a substantially higher MAPE value (58%) than that displayed by both SSM and SStM forecasts (27-37%). Large magnitude deviations between SEPB forecasts and actual returns tend to occur in consecutive years which seriously erodes the confidence of harvest managers as well as the fishing industry in their utility.

SStM and SSM forecasts (451,000 and 771,000 sockeye respectively) indicate that returns of Barkley Sound sockeye will remain below the 20 year average (880,000) in 1998 but are likely to represent an improvement over both the 1996 and 1997 return years. SEPB suggests returns of 902,611 sockeye which would exceed the 20 year average return. Comparative performance of the various forecast options along with DFO's recent pursuit of a more risk averse approach to management recommends the SStM forecast range of 384,000 (75% probability) to 615,000 (25% probability) sockeye as the preferred, pre-season forecast for 1998.

Subcommittee Discussion

The paper was accepted by the Subcommittee. Barkley Sound forecasts have been relatively accurate and are an important component of the Barkley Sound management plan for sockeye. The Subcommittee suggested using all four of the model performance evaluation methods as outlined in Welch et al. (PSARC S94-16) and Wood et. al. (PSARC S95-12) rather than only the Mean Absolute Percent Error (MAPE) used in this report. The reporting of uncertainty in this report is inconsistent with the preferred probability distribution approach because of inherent differences in the approach used to forecast Barkley sockeye. The Subcommittee suggested an alternate approach to make the evaluation of uncertainty more consistent. The authors completed a revision and the probability distributions for the 1998 Barkley Sound sockeye forecasts are outlined in Table 3.

Subcommittee Recommendations

1. The Subcommittee recommends the SStM approach for Barkley Sound sockeye forecasts in 1998. The probability distribution of the forecasts is: 75% probability of a run larger than 384,000, 50% probability of a run larger than 451,000 and a 25% probability of a run larger than 615,000.

S98-5 1998 forecasts of marine survival rate, marine distribution and pre-fishery abundance for southern B.C. coho salmon. R. Kadowaki and B. Holtby.
Working paper accepted subject to revision

Forecasts of marine survival rate, marine distribution and pre-fishery abundance for southern B.C. coho in 1998 were generated using methods similar to those used in previous years. However, abundance forecasts were for two stock aggregates (INSIDE - Strait of Georgia, Fraser River, Johnstone Strait; OUTSIDE - west coast of Vancouver Island) rather than for the WCVI troll fishing area as contained in previous working papers. The stock aggregate forecasts are now required by fishery managers to plan fisheries throughout the range of southern B.C. coho stocks and not just for the WCVI troll fishing area.

Four methods of producing marine survival rate forecasts were presented; a sibling regression (SibR) model, a ratio method (RAT1: ratio of survivals is constant, so any change observed will continue), a 3-year running average (3YRA) model, and a Like Last Year (LLY) model (note - This model simply says that the coming year will be like last year). Retrospective analysis indicated that the RAT1 and LLY models provided the best forecasts for Strait of Georgia coho because of the trending nature of coho survival in this area. For Robertson Creek coho (WCVI), the RAT1 and SibR models worked best. Results for the best models are summarized in Table 4.

Four methods were also examined to forecast marine distribution of catch; a salinity model (SAL), a ratio model, a 3YRA model and an LLY model. The salinity model worked best using February salinity at the Chrome Island light station. This model predicted a moderately strong outside distribution of Strait of Georgia coho. Qualitative information from research trawl and troll programs and from sport fishers indicates a very strong outside distribution pattern. Results for the best models are summarized in Table 4.

A 10% reduction from the 1996 reconstructed abundance for INSIDE and OUTSIDE aggregates was used to arrive at the 1997 abundance forecast. The abundance of these stock aggregates in 1996 was reconstructed by dividing catch by stock aggregate by an estimate of the mean exploitation rate applied to the stock aggregate. Stock composition data for the 1994 return year were used to partition the 1996 catch. The partitioning was based on a Pacific Salmon Commission model using CWT recoveries. A range of observed abundance for the 1997 return year was generated using mean exploitation rate values of 0.20, 0.25 and 0.30 and by supplementing CWT based stock composition estimates with DNA based estimates for the WCVI and Juan de Fuca sport fisheries. Three methods were examined for forecasting 1998 abundance; a 3YRA model, an LLY model and a ratio model that forecasts the coming year based on the ratio of last year to the previous year multiplied by last year. The LLY model worked best and results for it are summarized in Table 4.

The following points summarize the authors conclusions and recommendations:

1. The authors recommend that a forecast of marine survival in 1998 for Strait of Georgia hatchery indicator stocks using either the LLY or the RAT1 model be adopted. Both models perform well when marine survival is trending. The RAT1 model gives a more conservative and more precise forecast for Chilliwack, the most strongly trending of the hatchery indicators. The range of marine survival forecasts for these two models for Big Qualicum River, Chilliwack River and Quinsam River are 0.012–0.014, 0.015–0.024, and 0.012–0.014, respectively.

2. The sibling regression and RAT1 models worked best for Robertson Creek coho and produced a marine survival forecast of 0.030–0.044 (50% probability) for 1998.

3. The marine distribution of Strait of Georgia coho is likely to show a high outside pattern again in 1998. A salinity correlate (February at Chrome Island) indicates a moderately high outside distribution, while more qualitative information (research trawl and troll catches, observations by sport fishers) suggests a strong outside distribution as we saw in 1995, 1996 and 1997.

4. The authors recommend an LLY approach to forecasting the abundance of Strait of Georgia coho based on the fishery mortality reconstruction applied to the 1997 return. This produces a Strait of Georgia (including Fraser River) coho forecast of 363,607 (50% prob.) in 1998. Caution should be exercised in applying the 50% probability forecast since a similar approach for 1997 produced an over-forecast of the return, and the RAT1 model predicted considerably lower abundance for the INSIDE aggregate.

5. For the west coast of Vancouver Island, the LLY model produced a forecast of 176,225 (50% prob.). Returns might be higher than this because returns in 1998 are from a much greater spawning escapement than the return in 1997.

6. Reconstructions of abundance used in forecasting analyses would be greatly enhanced by more timely and stock specific estimates of fishery stock composition. Coded wire tag data are deficient for this purpose. A carefully designed DNA sampling program could provide this information for both domestic management and Pacific Salmon Commission purposes.

7. Please be aware that all forecasts of coho survival, distribution and abundance have high statistical uncertainty. The authors would urge that during periods of low abundance and marine survival such as now experienced, extreme caution (conservatism) be exercised in fishery management applications of these forecasts.

Reviewers' Comments

Reviewer #1

Reviewer 1 indicated that the paper reviews the available information to generate forecasts of total coho salmon abundance in southern BC. The reviewer noted that the paper is generally quite comprehensible, although there is lack of detail in certain areas that makes it difficult to assess the uncertainty in some of the estimated quantities. The poor performance of the abundance forecasts for 1997 is reason to be cautious about the use of the methods. It is suggested that in the future, formal time series methods be used for marine survival forecasts, and that all of the various sources of uncertainty be formally incorporated into the forecasts, possibly using Bayesian methods.

Reviewer #2

Reviewer 2 concluded that forecasts presented in this working paper satisfy the four general requirements of scientific forecasts: first, the quantities being forecasted (here survival of indicator stocks, P_{inside}, and abundance by stock aggregate) can be measured; second, the procedures used are documented well enough to allow others to reproduce the analyses in future assessments; third, the performance of alternative methods is compared in fair, retrospective analyses; and finally, forecasts are provided as probability distributions or with quantitative estimates of their uncertainty.

This reviewer also noted that confidence intervals for the 1998 forecasts are likely too narrow because not all sources of possible error were considered. However, he also pointed out that this deficiency should have little impact on the utility of advice presented because confidence intervals presented in the paper were already very wide. The reviewer had difficulty understanding (from the description in the working paper) how the standard deviation for the LLY estimates had been computed, but once explained by the authors, he agreed that the method used was reasonable, but suggested that the description in the working paper should be improved. He also recommended that in developing future forecasts such as these, where no biological data or insights are available to guide analysis, the authors explore more conventional time series analyses instead of the LLY method. The reviewer suggested using all four of the model performance evaluation methods as outlined in Welch et al. (PSARC S94-16) and Wood et. al. (PSARC S95-12, but acknowledged that the MSE criterion used by the authors ought to be similar, or intermediate to the other approaches.

Reviewer #3

The third reviewer focused on the relevance of the forecasts for setting up pre-season management strategies for southern coho. He concluded that the forecasts are reasonable, and that they provide a credible basis for the management of these stocks. The reviewer identified a number of issues that warrant consideration. The first issue relates to the forecasting methods. The forecasts may be optimistic. Since there is a downward trend since the mid to late 1980s the methods used may overpredict the

survival for 1998, as occurred for Strait of Georgia stocks in 1997. The second issue relates to stock composition data. Based on DNA sampling, the catch of West Coast of Vancouver island stocks of coho would fall to less than half the catch estimated by CWTs, and the interceptions of U.S. origin stocks and inside stocks increase substantially. The third issue is related to distribution. The evidence that Strait of Georgia coho will be on the West Coast of Vancouver Island again in 1998 is reasonable. However, the reviewer cautions that during strong El Niño years (e.g. 1992 and 1993), significant numbers of coho remained inside. The reviewer points out that we are currently in an other intense El Niño event and recommends that the coho distribution be closely monitored in 1998.

Subcommittee Discussion

The Subcommittee discussed the issue raised by the reviewers that survival forecasts may be overestimated. The possibility that the best model may be a linear regression of recent years because of the downward trend in survival was discussed. The authors pointed out that actually there was not a declining trend for Robertson Creek coho since 1991, the Big Qualicum trend was downward for the last four years. The Subcommittee noted that survivals of the Quinsam and Chilliwack indicators had declined over the last decade. A suggestion to use time series methods was made to address this issue (this should be available for inclusion in this report). The Subcommittee noted that if the trend of decreasing survival for the inside indicators continued in 1998 the coho forecasts would be over estimates, and is grounds for a cautious approach.

Stock composition estimates were derived using a methodology developed by the Pacific Salmon Commission, Coho Technical Committee. The most recent composition data available was from the 1994 fishery. The 1994 data were applied to estimate the 1995, 1996 and 1997 abundance. This introduces more uncertainty into the estimates but is the best approach currently available. Other difficulties with the abundance estimates were related to exploitation estimates only from three hatchery stocks and uncertain estimates of total mortality estimated for non-retention fisheries. The Subcommittee noted that this additional uncertainty is not captured in the model forecasts probability distributions (and cannot be estimated). For this reason the Subcommittee suggests a conservative approach to applying the forecasts in 1998.

Reconstructions of abundance used in forecasting analyses would be greatly enhanced by more timely and stock specific estimates of fishery stock composition. Coded wire tag data are deficient for this purpose. A carefully designed DNA sampling program could provide this information for both domestic management and Pacific Salmon Commission purposes.

The Subcommittee suggests that the lower range of the forecasts be used to determine coho management action for 1998 for Strait of Georgia coho. This conservative approach is recommended for three reasons: 1) there is a downward trend in survival for the inside stocks, 2) the 1997 survival has been overestimated using the same methods as for 1998, and 3) the stock composition data are uncertain for allocating catch to the appropriate stock.

The marine distribution of Strait of Georgia coho is likely to show a high outside pattern again in 1998. A salinity correlate (February at Chrome Island) indicates a moderately high outside distribution, while more qualitative information (research trawl and troll catches, observations by sport fishers) suggests a strong outside distribution as we saw in 1995, 1996 and 1997.

Subcommittee Recommendations

1. The Subcommittee recommends adoption of a forecast of marine survival in 1998 for Strait of Georgia hatchery indicator stocks using the LLY or RAT1 model. The range (50% probability) of marine survival forecasts for these two models for Big Qualicum River, Chilliwack River and Quinsam River are 0.012–0.014, 0.015–0.024, and 0.012–0.014, respectively.

2. The sibling regression and RAT1 models worked best for Robertson Creek coho and produced a marine survival forecast of 0.030-0.040 (50% probability) for 1998, the same as the 1997 return.

3. The Subcommittee recommends an LLY approach to forecasting the abundance of Strait of Georgia and west coast Vancouver Island. The forecast probability distribution for the Strait of Georgia (including Fraser River) coho in 1998 is: 75% probability of a run larger than 280,000; 50% probability of a run larger than 365,000; and a 25% probability of a run larger than 485,000. The forecast probability distribution for west coast Vancouver Island coho in 1998 is: 75% probability of a run larger than 125,000; 50% probability of a run larger than 175,000; and a 25% probability of a run larger than 245,000.

4. The Subcommittee recommends that during periods of low abundance and marine survival such as we are experiencing, a conservative approach be exercised in fishery management applications of these forecasts. All forecasts of coho survival, distribution and abundance have high statistical uncertainty.

4. Tables and Figures

Table 1 Fraser River run size forecasts of age-4 and age-5 sockeye by stock and timing group (bolded) for 1998.

	Probability of Achieving Specified Run Sizes[a]				
STOCK/TIMING	**25%**	**50%**	**75%**	**80%**	**90%**
Early Stuart	**321000**	**175000**	**97000**	**84000**	**58000**
Driftwood	38000	13000	4000	3000	2000
non-Driftwood	283000	162000	93000	81000	56000
Early Summer	**1436000**	**642000**	**296000**	**245000**	**150000**
Fennell	57000	30000	16000	14000	9000
Bowron	38000	22000	13000	11000	8000
Raft	18000	9000	5000	4000	3000
Gates	49000	26000	14000	12000	8000
Nadina	39000	22000	13000	11000	8000
Pitt	84000	46000	25000	22000	15000
Seymour	215000	116000	63000	54000	36000
Scotch	936000	371000	147000	117000	63000
Mid Summer	**11525000**	**6647000**	**3862000**	**3376000**	**2364000**
Chilko	2269000	1411000	878000	780000	569000
Quesnel	7489000	4298000	2467000	2148000	1486000
Stellako	856000	545000	348000	311000	230000
LateStuart	911000	393000	169000	137000	79000
Late Summer	**5519000**	**3754000**	**2567000**	**2335000**	**1819000**
Birkenhead	513000	303000	179000	157000	111000
Late Shuswap	4250000	2994000	2109000	1932000	1531000
Cultus	34000	18000	10000	8000	5000
Portage	93000	45000	21000	18000	11000
Weaver	629000	394000	248000	220000	161000
TOTAL	**18801000**	**11218000**	**6822000**	**6040000**	**4391000**

[a] probability that the actual run size will exceed the specified forecast

Table 2 Total expected return of Johnstone Strait, Georgia Strait and lower Fraser River chum salmon for 1998.

STOCK TYPE	AGE 3	AGE 4	AGE 5	TOTAL
Fraser River Wild	432,000	1,221,000	83,000	1,736,000
Fraser River Enhanced	18,000	103,000	15,000	136,000
Non-Fraser River Wild	168,000	1,160,000	141,000	1,469,000
Non-Fraser River Enhanced	32,000	262,000	59,000	353,000
Total Fraser River	450,000	1,324,000	98,000	1,872,000
Total Non-Fraser River	200,000	1,422,000	200,000	1,822,000
Grand Total	650,000	2,746,000	298,000	3,694,000
Percent	18%	74%	8%	100%
WILD CHUM SALMON ESTIMATES ONLY				
Probability of achieving denoted run size or greater				
90%				623,000
75%				1,847,000
50%				3,205,000

Table 3. Barley Sound sockeye return forecasts for 1998.

Probability of Achieving Specified Run Sizes*

Forecast	25%	50%	75%	90%
SStM	615000	451000	384000	292000
SSM	1020000	771000	436000	231000
SEPB	1019000	902611	336000	NA<0

* probability that actual run size will exceed the specified forecast.

Table 4. Summary of recommended marine survival, distribution and abundance forecasts for southern B.C. coho salmon in 1998.

	Best Models	Probability of Achieving at Least the Specified Value		
		50%	75%	90%
Marine Survival				
Big Qualicum	RAT1–LLY	0.012–0.014	0.008–0.009	0.006–0.006
Quinsam	LLY–RAT1	0.012–0.014	0.007–0.023	0.007–0.012
Chilliwack	RAT1–LLY	0.015–0.024	0.012–0.019	0.010–0.015
Robertson	SibR–RAT	0.030–0.044	0.021–0.023	0.021–0.012
Distribution (proportion inside)				
Big Qualicum	SAL	0.239	0.172	0.118
Quinsam	SAL	0.257	0.191	0.136
Chilliwack	SAL	0.139	0.076	0.033
Combined	SAL	0.226	0.173	0.130
Abundance				
Originating Inside[1]	LLY	363,607	278,126	216,024
Originating Outside[2]	LLY	176,225	126,818	92,994

[1] Abundance of stocks originating from the Strait of Georgia, Fraser River and Johnstone Strait.

[2] Abundance of stocks originating from West coast Vancouver Island.

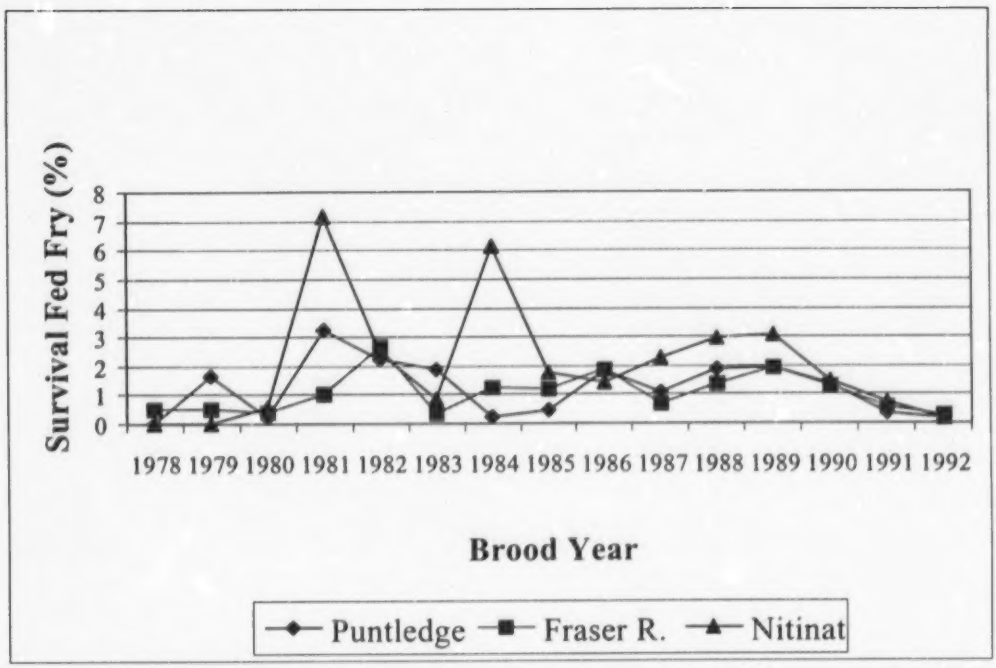

Fig. 1 Survival south coast chum fry released from enhancement facilities

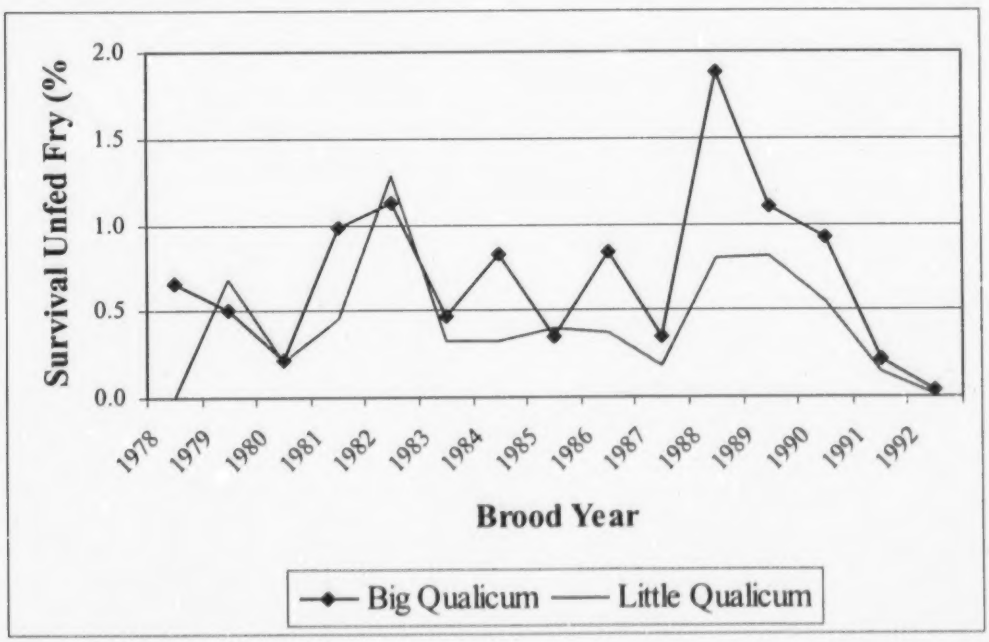

Figure 2 Survival South Coast chum fry released from enhancement facilities

5. APPENDIX 1 Participants at the March 18, 1998 meeting of the Salmon PSARC Subcommittee.

Subcommittee Chair: Dave Peacock
PSARC Chair: Max Stocker

Subcommittee Members:

D. Anderson
S. Argue
D. Bailey
A. Cass
B. Hargreaves
B. Holtby
K. Hyatt
R. Kadowaki
A. MacDonald
S. McKinnell
P. Ryall
M. Sullivan
C. Wood

Observers:

R. Beamish
G. Caw
T. Gjernes
W. Leudke
B. Otway
B. Shaw
B. Snyder
D. Welch
K. Wilson

6. APPENDIX 2 Reviewers of Working Papers

Working Paper	Reviewers
S98-5	Mike Bradford David Welch Chris Wood